# Timing Resolution of an LAPPD Prototype Measured with CERN PS Test Beams

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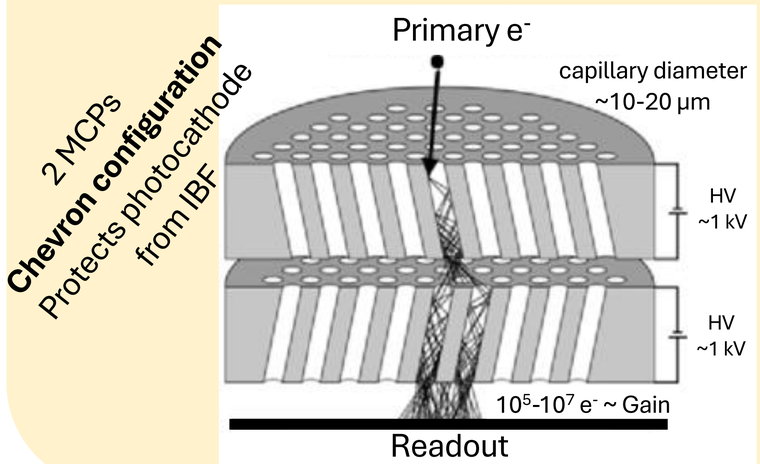
## LAPPD – an MCP-PMT based Photodetector

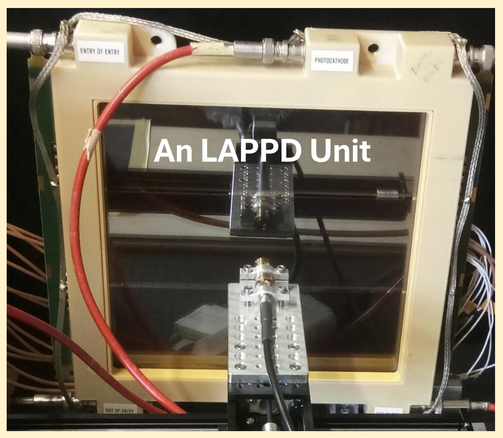
MicroChannel Plates[1] (MCPs) are **vacuum based Photomultipliers**




- Continuous dynode for e⁻ multiplication
- **Operation in strong magnetic field ~ 1T**
- **Excellent time resolution ( < 100 ps) for SPE**
- Low noise, High QE, **High gain O ($10^6$)**
- Good radiation hardness

- **Atomic Layer Deposition (ALD)**
  – efficient technique for increasing detector lifetime
- Commercially available
  – Hamamatsu, Photek, etc.

Large Area Picosecond Photo-Detectors[2] **(LAPPDs)**
- MCP based technology



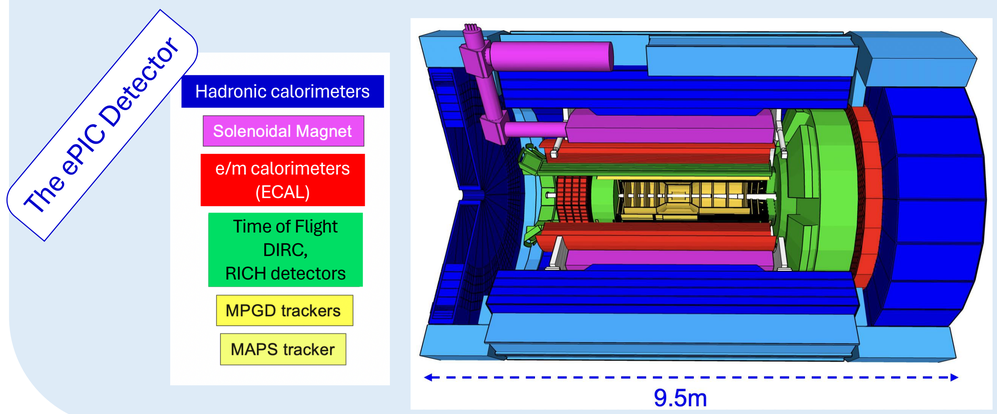

Application:
- **Cherenkov Imaging Devices**
  e.g., RICH, DIRC
- TOF, timing layers of Calorimeters

**Large Area Coverage –** cost effective solution for PDs in HEP

## HRPPDs – in the EIC ePIC

LAPPD – A **potential first step** towards High Rate Picosecond Photo-Detector **(HRPPD)** – technically different from LAPPD **(10 cm vs. 20 cm** size and **DC vs. capacitive coupling** )

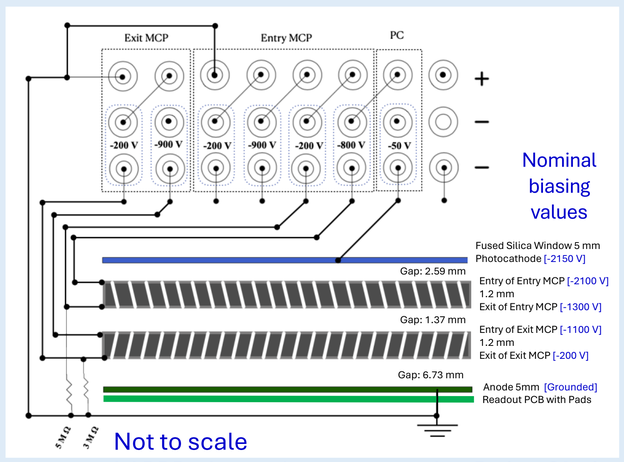
- ePIC[3] @ the Electron Ion Collider[4] (EIC): Ultimate **QCD** exploration
- NSAC LRP 2023: "... the EIC as the highest priority for facility construction."
- HRPPDs in ePIC: photosensors for **Cherenkov Imaging PIDs**
  - **proximity focusing RICH** and **TOF information** (backward Endcap)
  - **high performance DIRC** (Barrel)




## The LAPPD Sensor

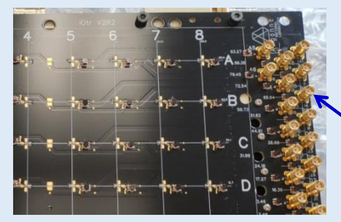
**LAPPD unit no. 124** of type "**Generation II** (resistive Anode)" by Incom.
- Bialkali PhotoCathode (PC)
- Two MCP (20 μm-diameter capillaries) layers
- Resistive Anode - coating with Cr layer
- Capacitively coupled readout[5] sensors (8x8 square pads of 1 inch) on PCB

- active area ~20 x 20 $cm^2$




Not to scale

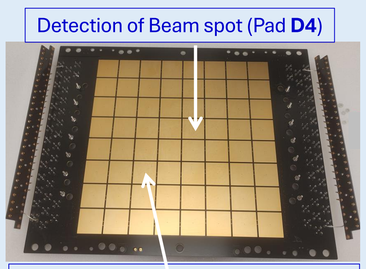
LAPPD electrodes connected to **Daisy Chain HV Power Supply (CAEN DT1415)**




One quarter of the PCB

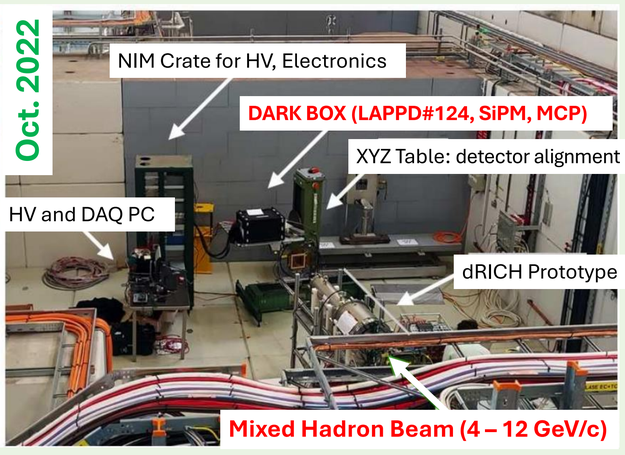
SMA connectors

Detection of Beam spot (Pad **D4**)



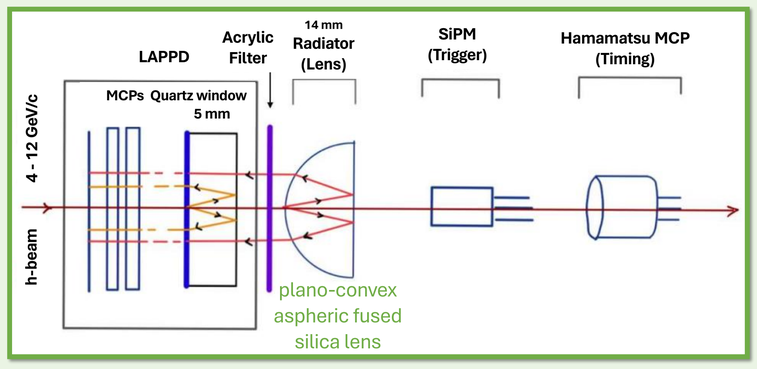
Detection of SPEs in Cherenkov Ring (**F6**-One of the Pads)

## Beam test Set-up and TDAQ




**CERN PS T10** beam facility shared with ePIC dual-RICH prototype

- Cherenkov light production by hadrons in the LAPPD window and downstream lens
- Light returns at PC after total internal reflections
- Good focusing of Cherenkov ring photons. <2 PE>/pad
- Use of Acrylic (UV) filter to reduce <# PE>/pad

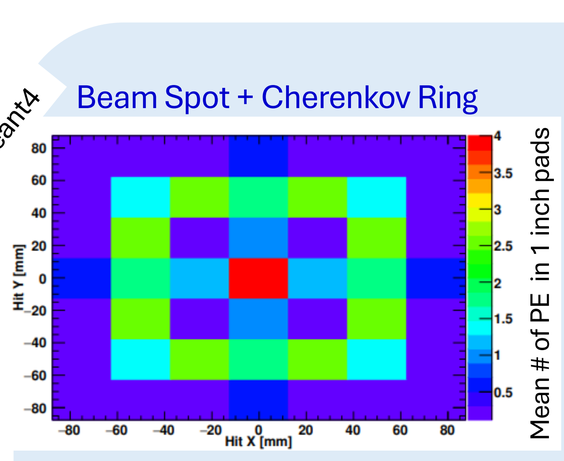



| Inside Dark Box | Serving Purpose | # of Channels |
|---|---|---|
| LAPPD | Radiator Light Cone & Beam Spot detection | 31 |
| SciFi + SiPM | Fast Trigger/ Beam Monitor | 2 |
| Hamamatsu MCP | Timing Reference | 1 |

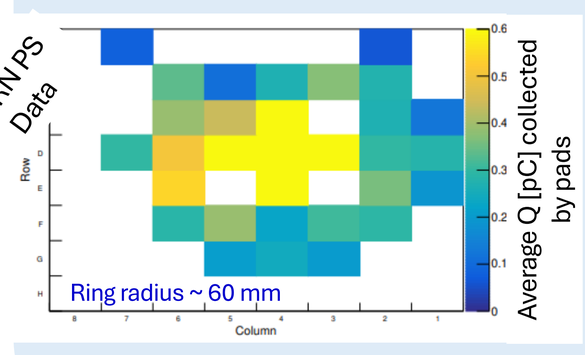
32+2 TR signals read-out & digitized by **CAEN V1742 Digitizer [CAEN WaveDump Software]**

## Simulation and Experimental Results on Timings

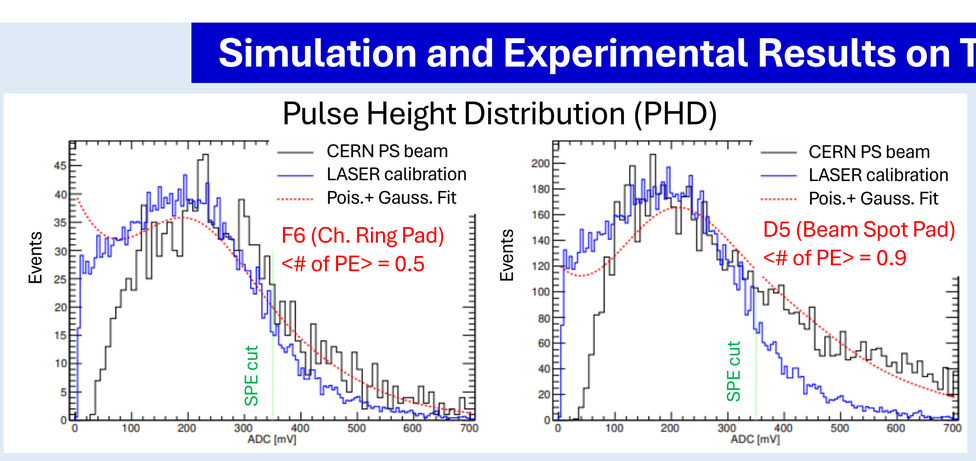
Geant4 — Beam Spot + Cherenkov Ring

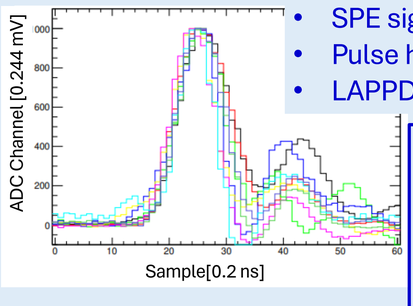



CERN PS Data




Pulse Height Distribution (PHD)

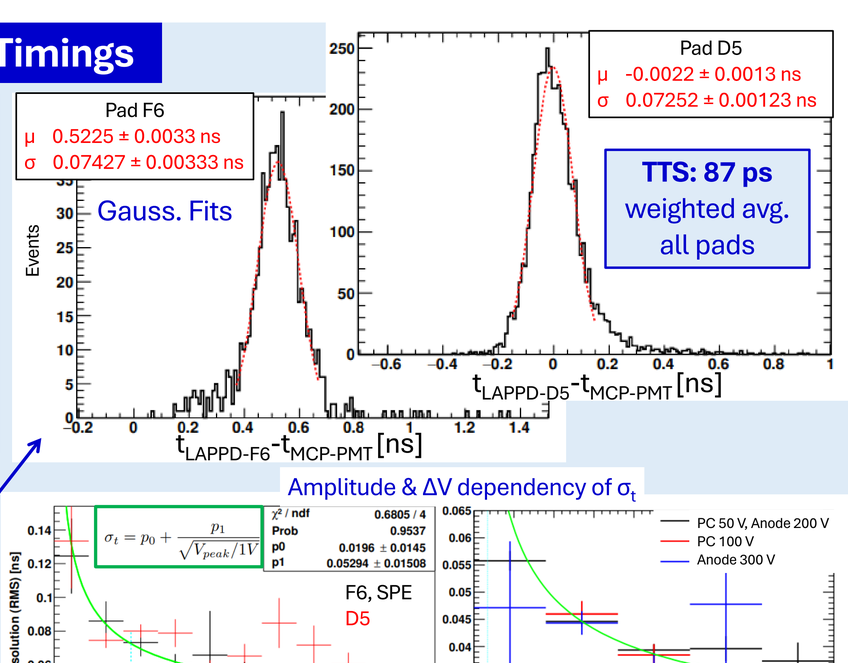



- SPE sig. amplitude: working range of timing studies
- Pulse height ~ charge distribution [pC]
- LAPPD Gain (nominal bias): **6.9 ± 0.7 x $10^6$**

**Digitized LAPPD signal selection**
- Amplitude > 25 mV
- Arrival time ±2 ns from SciFi
- Correct signal shape: cross-talk excluded

Strategy:
- Linear fit: 10-90% peak height of rising edge
- $T_{signal,\ arrival}$: @ 50% peak height on the fit line
- Transit Time Spread [TTS]:
  $\sigma\ [T_{signal,\ arrival}\ (LAPPD) - T_{signal,\ arrival}\ (MCP)]$




Amplitude & ΔV dependency of $\sigma_t$




ΔV_MCPs: 750/800 V ~ 17 mV ~ SPE; 400 mV ~ 23 PE
$\sigma_1$ = 80 ps/√23; $\sigma_2$=18 ps (G4); $\sigma = \sqrt{(\sigma_1)^2 + (\sigma_2)^2}$ ~ 25 ps
**Strategy is capable of measuring as fine as ~ 25 ps**

## References

1) T. Gys et al., Micro-channel plates and vacuum detectors. NIMA 787 (2015) 254-260.
2) A. Lyashenko, et al., Performance of large area picosecond photo-detectors. NIMA 958 (2020) 162834.
3) R. A. Khalek, et al., Science Requirements and Detector Concepts for the Electron-Ion Collider: EIC Yellow Report, NIMA 1026 (2022) 122447.
4) A. Accardi, et al., Electron Ion Collider: The Next QCD Frontier - Understanding the glue that binds us all, Eur. Phys. J. A 52 (2016) 268.
5) S. Shin et al., Advances in the Large Area Picosecond Photo-Detector (LAPPD): 8x8 MCP-PMT with Capacitively Coupled Readout, 2022.

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